Space Technology Research Grants

Interfacial Instability in Two-Phase Flow: Manipulating Coalescence and Condensation

Completed Technology Project (2011 - 2015)

Project Introduction

Two-phase flow under microgravity conditions presents a number of technical challenges (and). Life support and habitation depend on systems that use two-phase flow (Human Health, Life Support and Habitation Systems, , Figure 2) as do Thermal Management Systems (). The central goal stated in is to develop systems with reduced mass that are capable of handling high heat loads with fine temperature control. For example, this applies to a two-phase pumped loop system (section 2.2.3.2) where waste heat is stored as latent heat. In order to achieve the goals stated above, it is necessary to understand how the physics of pool boiling and drop-wise condensation are affected by low gravity. Maintenance of high heat-transfer in both processes along with efficient means of condensate removal and collection are keys to achieving high heat loads. In pool boiling, the heat transfer is limited by how fast the bubbles can be removed from the heat-transfer surface. Under microgravity where buoyancy is absent, coalescence of smaller sized bubbles into a larger bubble next to the surface is favored. Therefore the heat transfer will be substantially lower because of the inability to sustain liquid contact at the heater surface. Furthermore, forced convection will be weaker because of slower detachment rates. In drop-wise condensation, traditional condensate removal methods have relied on gravity. The proposed work seeks to overcome the limitations of low-gravity by instituting both passive (surface-energy gradients) and active (mechanical excitation) ways to control wettability of drops, thereby allowing for directed drop motion. The drop transport rate, or the rate at which the drops can be cleared from the surface, will be a function of nucleation, growth and coalescence rates. A device which 'simulates' condensation under low gravity will be used to decouple and quantify these effects. The device consists of a perforated glass plate where the drops are fed through the micron-sized holes using a syringe pump from a reservoir connected below the plate. Nucleation rates will be studied by modeling the dependence of drop shape, contact-line deformation, and growth rate of nucleating drops on the type and geometry of surface inhomogeneity (cavity versus long skinny crack) and density of sites. A physical model predicting under what conditions liquid will remain trapped in a cavity will also be developed. Drop growth will be studied by modeling how the dynamic contact-angle, position and velocity of the drop change for each of the three potential modes of growth: coalescence with other drops, collection of the liquid film trail left by another drop, and condensation from the saturated vapor directly onto the drop. Image analysis will be used to calculate the parameters of interest stated above. A final goal will be to compare and contrast the 'simulated' condensation with actual condensation. Three surface treatments will be used on the device: a purely superhydrophobic coating, a wettability gradient created by vapor-diffusion of a silane compound, and a series of nanoscale spikes which force the drop into a Cassie state combined with application of a macroscopic wettability gradient. Questions such as how the distribution of the drops will change with time, how the distributions will affect nucleation, growth and coalescence rates and how the distributions will

Project Image Interfacial Instability in Two-Phase Flow: Manipulating Coalescence and Condensation

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Organizational Responsibility

Responsible Mission Directorate:

Space Technology Mission Directorate (STMD)

Responsible Program:

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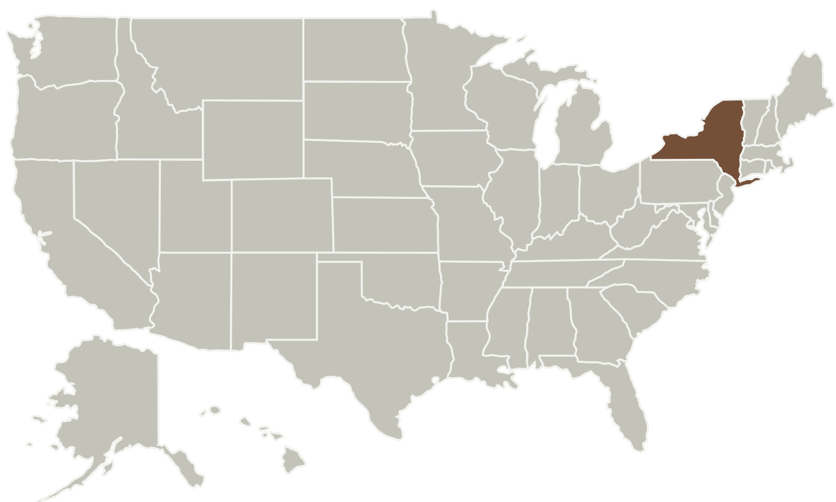
vary between the three surfaces will be answered by collecting statistics on the drops. The distributions will be used as a diagnostic tool to figure out the dominate rates.

Anticipated Benefits

Life support and habitation depend on systems that use two-phase flow (Human Health, Life Support and Habitation Systems) as do Thermal Management Systems. The central goal stated is to develop systems with reduced mass that are capable of handling high heat loads with fine temperature control. In order to achieve those goals, it is necessary to understand how the physics of pool boiling and drop-wise condensation are affected by low gravity. Maintenance of high heat-transfer in both processes along with efficient means of condensate removal and collection are keys to achieving high heat loads.

Primary U.S. Work Locations and Key Partners



Organizations Performing Work	Role	Type	Location
Cornell University	Supporting Organization	Academia	Ithaca, New York

Project Management

Program Director:

Claudia M Meyer

Program Manager:

Hung D Nguyen

Principal Investigator:

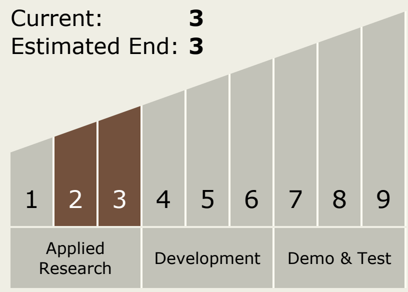
Paul Steen

Co-Investigator:

Ashley M Macner

Technology Maturity (TRL)

Start: **2**
Current: **3**
Estimated End: **3**



Technology Areas

Primary:

- TX14 Thermal Management Systems
  └ TX14.2 Thermal Control Components and Systems
    └ TX14.2.3 Heat Rejection and Storage

Primary U.S. Work Locations

New York

Images

4864-1363186966406.jpg
Project Image Interfacial Instability in Two-Phase Flow: Manipulating Coalescence and Condensation
(https://techport.nasa.gov/image/1784)

Project Website:

https://www.nasa.gov/directorates/spacetech/home/index.html